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Norwegian Institute of Public Health

memo

COVID-19-EPIDEMIC :

Transmission of SARS-CoV-2 via contact and droplets, 1st update – a rapid review

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Key messages

The findings in this memo are based on rapid PubMed searches. One researcher went through all search records, selected and summarised the findings. In the current situation, there is an urgent need for identifying the most important evidence quickly. Hence, we opted for this rapid approach despite an inherent risk of overlooking key evidence or making misguided judgements.

We identified six eligible reviews and 15 eligible primary studies. Eligible studies were summarised in text and tables.

Available evidence suggests that SARS-CoV-2, SARS-CoV and MERS-CoV can survive on inanimate surfaces for hours or days. Less is known about the virulence of virus deposited on inanimate surfaces.

Available evidence shows that SARS-CoV-2 tends to transmit between closely related individuals. Indirect transmission through inanimate surfaces (fomites) may also occur, but as available studies are performed in a laboratory or hospital setting it remains unclear to what extent contaminated surfaces constitutes a risk transmission in a community setting. A mathematical modelling study suggests that the relative contribution of environmental transmission in a community setting is considerably lower than direct contact, but these results are very uncertain.

It is very challenging to acquire strong evidence regarding the relative importance of different routes of transmission. People in close relations and people staying in close proximity to each other are exposed to multiple ways of transmission. General infection prevention measures will also affect multiple routes of transmission.

Hovedfunn (Norwegian)

Funnene i denne hurtigoversikten baserer seg på raske søk i PubMed. Én forsker har gått gjennom søketreff, valgt ut og oppsummert resultatene. Ettersom det har vært viktig å få fram forskningsresultatene raskt, har vi valgt denne framgangsmåten, selv om det innebærer risiko for at vi kan ha oversett viktig dokumentasjon og kan ha gjort feilvurderinger underveis.

Vi identifiserte seks systematiske oversikter og 15 enkeltstudier. De inkluderte studiene er oppsummert i tekst og i tabeller.

Tilgjengelig dokmentasjon tyder på at SARS-CoV-2, SARS-CoV og MERS-CoV kan overleve på overflater i timer eller dager, men vi vet mindre om smittsomheten til virus som avsettes på overflater.

Flere studier viser at SARS-CoV-2 har en tendens til å smitte mellom mennesker som oppholder seg i nærheten av hverandre. Indirekte smitte via virus som avsettes på overflater (fomites) kan forekomme, men forskningen er utført i laboratorier eller på sykehus, og det er uklart i hvilken grad indirekte kontaktsmitte er viktig med tanke på smitteutbredelse i samfunnet. En matematisk modelleringsstudie antyder at det relative bidraget fra indirekte kontaktsmitte er betydelig lavere enn for direkte kontakt, men disse resultatene er svært usikre.

Det er veldig utfordrende å skaffe sterke bevis for den relative betydningen av forskjellige smitteveier. Mennesker i nære relasjoner og mennesker som oppholder seg i nærheten av hverandre utsettes for ulike smitteveier. Mange smitteforebyggende tiltak vil også påvirke flere mulige smitteveier.

Content

Introduction

Updated evidence on possible transmission routes is essential in order to give appropriate advice on infection control measures. As a part of the Norwegian Institute of Public Health's role in handling the COVID-19 epidemic, we have been commissioned to prepare a rapid summary of the available research on the role of droplets and contact in the transmission of SARS-CoV-2.

Methods

Questions of interest

In this rapid summary we want to identify available research on the role of droplets and contact in the transmission of SARS-CoV-2. The main question is subdivided into four sub-questions

- To what extent can SARS-CoV-2 be detected in environmental samples?
- What do transmission tracking studies tell us about transmission routes?
- What can modelling studies tell us about transmission routes?
- What do we know about transmission routes for SARS-CoV and MERS-CoV?

Searches

We conducted two simple searches for literature in the PubMed on the 5th of May 2020. One of the searches aimed at identifying systematic reviews about transmission of SARS-CoV-2, MERS-CoV and SARS-CoV (Appendix A), and the other search aimed at identifying primary studies about transmission of SARS-CoV-2 via droplets and close contact (Appendix B).

We went through reference lists of relevant studies in order to identify studies not retrieved in the main searches, and we performed supplementary searches in the LitCovid-database using the terms “transmission routes” or “transmission models”.

Study selection

We included and categorised reviews and primary studies according to the questions mentioned above.

One researcher screened all records from the search, selected and summarised the study findings. Due to time constraints, we were not able to formally assess the quality of included studies or the quality of the evidence.

Peer review

The searches for literature were prepared in collaboration with Elisabet Hafstad (Information Specialist). Vigdis Lauvrak (Senior Researcher, Norwegian Institute of Public Health), Gerd Flodgren (Senior Researcher, Norwegian Institute of Public Health), Frode Forland (Research Director, Norwegian Institute of Public Health), Solveig Jore (Senior Advisor, Norwegian Institute of Public Health), Hilde Marie Lund (MD, Norwegian Institute of Public Health) and Oliver Kacelnik (MD, Norwegian Institute of Public Health) read swiftly through a draft of this document before publication.

When preparing this review we have chosen a very rapid approach as it has been imperative to obtain the research results quickly, even though it is associated with a certain risk of overlooking important publications and making errors.

Results

Included studies

Systematic reviews

We included six systematic reviews following searches in databases and snowballing, i.e. manual searches in reference lists of relevant studies (1-6). The quality of the included reviews was impaired by limitations in search strategies and because the review authors did not assess the quality or risk of bias in included primary studies.

Primary studies

The search for primary studies returned 376 unique records. All were accepted for publication in peer-reviewed journals. We included 15 studies with some potential to inform knowledge about possible routes of transmission. The available studies were categorised into three main categories: 1) Six studies aimed at detecting SARS-CoV-2 in environmental samples from inanimate surfaces, 2) Eight studies aimed at tracing SARS-CoV-2 transmission, and 3) One study explored likely routes of transmission through mathematical modelling.

Detection of SARS-CoV-2 in environmental samples

We included six primary studies (Table 1). One in vitro study demonstrated that SARS-CoV-2 may survive on inanimate surfaces for several days, but the virus' ability to survive differs between materials (15). SARS-CoV-2 RNA is also detected on inanimate surfaces in hospital wards housing patients with COVID-19 (7, 9, 12), but not all studies confirm that surface contamination with SARS-CoV-2 is a real problem (7, 10). Importantly, a study from Italy showed that it is possible to confine the contamination to restricted areas (8).

The included studies suggest that SARS-CoV-2 can contaminate inanimate surfaces, but all available studies are performed in hospitals or in laboratories. It remains unclear to what extent contamination of surfaces constitute a risk of exposure to viable virus and virus transmission in a community setting. A systematic review published 30th April 2020 also stated that the evidence is too sparse to allow clear conclusions regarding the ability of SARS-CoV-2 to survive on inanimate surfaces is sparse (6).

Table 1 *Detection of SARS-CoV-2 on inanimate surfaces*

Authors	Material	Conclusion
Cheng et al. (7) Hong Kong	Samples taken from 13 surfaces in a COVID-19 patient room	One of the 13 samples positive for SARS-CoV-2 RNA
Colaneri et al. (8) Italy	16 surfaces in areas considered virus free were swabbed to search for COVID-19 RNA	All tested surfaces in anteroom, corridor and post-cleaning samples negative for SARS-CoV-2 RNA
Ong et al. (9) Singapore	Environmental samples from 26 sites at a SARS-CoV-2 outbreak centre. Samples Analysed using RT-PCR	Detected environmental contamination in 16 of 26 sites indicating that environment is a potential medium of transmission
Ong et al. (10) Singapore	Samples (n=90) from health care workers' (n=30) protective equipment in COVID-19 department. Typical activities: medication administration, cleaning, physical examination and collection of respiratory samples[A]	All 90 samples were negative
van Doremalen et al. (11) US	Comparison of surface stability of SARS-CoV and SARS-CoV-2 on copper, cardboard, stainless steel and plastic. In vitro study	SARS-CoV-2 and SARS-CoV show similar stability. Both viruses decay more slowly on plastic and stainless steel than on copper and cardboard
Ye et al. (12) China	Authors collected 626 surface swabs in a hospital during the COVID-19 outbreak.	Most contaminated zone was intensive care units taking care of patients with COVID-19. Objects with large proportion of positive tests were self-service printers, keyboards, doorknobs and hand sanitizer dispensers.

[A] No aerosol generating procedures were performed prior to or during sampling

Transmission tracing and likely routes of transmission

We included eight transmission tracing studies (Table 2). All the studies conclude that transmission usually occur between people who are in close contact, but one study report some cases where transmission may have occurred through contaminated inanimate surfaces (15). These results can be taken as indication that SARS-CoV-2 is transmitted in the community by a combination of droplets, direct and indirect contact. The studies are not designed to differentiate between various routes of transmission, and are inconclusive regarding the relative importance of various routes of transmission in the community.

Transmission modelling

We identified several transmission modelling studies in our searches. Many studies modelled the efficacy of various social distancing and shielding interventions, but we only identified one publication using mathematical models to explore the relative importance of transmission by droplet versus direct or indirect contact (21). In the latter study, the authors differentiate between symptomatic transmission, asymptomatic transmission, pre-symptomatic transmission and environmental transmission. Parameters used to inform the Bayesian infectiousness model were based on published data, anecdotal reports or indirect evidence. For a basic reproduction number of 2.0, the model suggested that the relative contribution of direct contact with pre-symptomatic (R_p=0.9) and symptomatic patients (R_s=0.8) clearly outweighs the contribution from environmental exposure (R_e=0.2) and direct contact with asymptomatic (R_a=0.1) people. The modelled results were associated with considerable uncertainties and wide credible intervals, and did not facilitate strong conclusions (21).

We did not find studies comparing the relative efficacy of intervention aimed at reducing transmission by droplets (e.g. face masks) and intervention typically reducing the risk of transmission by indirect contact (e.g. decontamination).

Table 2 *Studies exploring possible transmission routes between infected humans*

Authors	Material	Conclusion
Baettig et al. (13) Switzerland	Retrospective analysis of early COVID-19 cases among Swiss Armed Forces	Two confirmed cases had very limited direct contact, but both had contact to a third person who was likely an asymptomatic carrier of SARS-CoV-2
Chan et al. (14) China	Investigating family cluster of SARS-CoV-2 infection	Transmission between people in close contact
Cai et al. (15) China	Investigation of relationship and points of contact between people (n=35) in a cluster of COVID-19-cases in a shopping mall	Cases on floor 7 had been in direct contact, but no evident direct link between cases on floor 7 and cases on the other floors. Workers on all floors share elevators and restrooms, and may indicate indirect transmission (fomites)
Li et al. (16) China	425 patient with SARS-CoV-2 acquired pneumonia	Transmission between humans is most likely to occur by the means of direct physical contact[A]
Liu et al. (17) China	115 patients with SARS-CoV-2	Transmission between humans is most likely to occur by the means of direct physical contact[A]
Pung et al. (18) Singapore	Analyse contact between 36 patients with COVID-19 within three clusters comprising 6, 11, and 20 individuals	People who were infected did not always know each other, but transmission can usually be tracked down to direct physical contact[A]
Xia et al. (19) China	Investigating family cluster of SARS-CoV-2 infection	Transmission between people in close contact for long time, e.g. dining together
Wong et al. (20) Hong Kong	Surveillance of seven hospital workers and ten patients who had close contact with a patient with COVID-19	SARS-CoV-2 was not transmitted to any of the close contacts. Authors conclude that nosocomial transmission can be prevented through basic infection control measures.

[A] Transmission may have occurred through droplets, direct and indirect contact. Not possible to distinguish different routes of transmission

Transmission routes for SARS-CoV and MERS-CoV

SARS-CoV-2 is a corona virus, and it is likely that it shares some characteristics with other corona viruses, particularly SARS-CoV and MERS-CoV. For this reason, we decided to include systematic reviews and scoping reviews about transmission dynamics in other coronaviruses. We included the five reviews listed in Table 3. Key findings reported in each of the reviews are briefly summarised below.

Table 3 *List of included reviews about SARS-CoV and MERS-CoV*

Authors	Type of review	Question
Kramer et al. 2006 (1)	Systematic review	Infectivity of SARS-CoV after deposition in clinical specimens and on different surfaces
Kampf et al. 2020 (2)	Systematic review	Persistence of SARS-CoV, MERS-CoV and other coronaviruses on inanimate surfaces
Dawson et al. 2019 (3)	Systematic review	Virology, clinical characteristics, epidemiology and transmission of MERS-CoV
Otter et al. 2016 (4)	Systematic review	The role of dry surface contamination in transmission of SARS-CoV and MERS-CoV.
La Rosa et al 2020 (5)	Scoping review	Occurrence, persistence and concentration of corona viruses in water environments

Overview of included reviews

Kramer and co-workers summarized studies about the persistence of different pathogens (1). This systematic review does not include evidence on the persistence of MERS-CoV or SARS-CoV-2, but it cites one publication on the SARS-CoV virus (22). The study measured the virulence of the virus after deposition in clinical specimens and on different household surfaces, e.g. wood, glass and paper. Virulence was measured by inoculating the virus into cultured cells. In brief, the study showed that SARS-CoV can survive on inanimate surfaces and remain infectious for several days. The virulence of SARS-CoV was strongly reduced following heating or UV irradiation (22).

In January 2020, Kampf and co-workers reviewed literature about the persistence of coronaviruses (3). The authors included 22 studies. None of the included studies investigated SARS-CoV-2, but data from SARS-CoV, MERS-CoV and other coronaviruses suggests these viruses can persist on inanimate surfaces (metal, glass or plastic) for up to nine days. However, the viruses seem to be efficiently removed following some standard disinfection procedures (3).

Dawson and colleagues have published a thorough systematic review about MERS-CoV in which they also summarise evidence on possible transmission routes (4). Transmission between patients seems to be associated with close contact, for example in crowded emergency rooms, but some studies suggest direct contact can only explain ten percent of the cases. A South Korean study confirms the existence of MERS-CoV viral RNA on environmental surfaces on patient rooms, which may suggest a risk of fomite transmission. On the other hand, there are few known incidences of transmission to hospital laundry or maintenance workers, and the review authors point out this may indicate the risk of such transmission is low.

Otter and colleagues published a systematic review based on simple searches in PubMed (5). The authors aimed to assess the role of dry surface contamination in transmission of SARS-CoV and MERS-CoV. There are methodological differences between the available primary studies, but in-vitro studies suggest MERS-Cov and SARS-CoV can survive on dry surfaces for a longer period of time than influenza virus and other human coronaviruses (days vs. hours) (5). Survival time depends on the surface material, and more concentrated viral suspensions seem to survive longer. The review authors further state that "*…two studies have detected environmental reservoirs of SARS-CoV RNA by PCR, but no viable virus by culture*." The authors conclude that SARS-CoV may transmit by direct contact, indirect contact, droplets and aerosols, but that the relative importance of these routes is difficult to determine.

In April 2020, La Rosa and coworkers published a scoping review about persistence of coronavirus in water environments (5). The authors included 12 studies. Among other findings they report that coronavirus seems to have low stability in water, and that it is inactivated significantly faster than non-enveloped human enteric viruses. Coronavirus also seems to be sensitive to oxidants like chlorine.

Discussion and conclusion

Systematic reviews conclude that viruses that resembles SARS-CoV-2, i.e. SARS-CoV and MERS-CoV, are likely to transmit through a combination of different transmission paths. Currently available evidence suggests this is the case also for SARS-CoV-2. The virus seems to transmit between closely related individuals, but indirect transmission through inanimate surfaces (fomites) may also occur. So far, however, all studies detecting SARS-CoV-2 contamination of inanimate surfaces have been performed in hospitals or in laboratories. It remains unclear to what extent contamination of surfaces constitute a risk of exposure to viable virus and virus transmission in a community setting.

One statistical modelling study suggests that the contribution of environmental transmission is less important for transmission in the community than direct contact with symptomatic or pre-symptomatic patients, but these results are uncertain. It is very challenging to acquire strong evidence regarding the relative importance of different routes of transmission. People in close relations and people staying in close proximity to each other are likely to be exposed to multiple potential ways of transmission.

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Attachment

Search strategies

A) Search for systematic reviews (conducted 5. May 2020).

((Coronavirus[mh] OR "Coronavirus Infections"[mh] OR "SARS virus"[mh] OR "Severe Acute Respiratory Syndrome"[mh] OR "Middle East Respiratory Syndrome Coronavirus"[mh] OR "covid-19"[nm] OR "severe acute respiratory syndrome coronavirus 2"[nm] OR "corona virus"[tw] OR coronavirus[tw] OR coronovirus[tw] OR "COVID-19"[tw] OR COVID19[tw] OR CORVID-19[tw] OR CORVID19 OR nCoV[tw] OR 2019nCoV[tw] OR "SARS-CoV-2"[tw] OR "SARS-CoV2"[tw] OR SARSCoV19[tw] OR HCoV-19[tw] OR WN-CoV[tw] OR SARS[tw] OR "Severe Acute Respiratory Syndrome"[tw] OR MERS[tw] OR "Middle East Respiratory Syndrome"[tw]) AND ("Equipment Contamination"[mh] OR vehicle*[tw] OR contaminat*[tw] OR "direct contact"[tw] OR fomite*[tw] OR fomes[tw] OR hand[tw] OR hands[tw] OR skin[tw] OR surface*[tw]) AND systematic[sb])

B) Search for primary studies (conducted 5. May 2020)

Restricted to SARS-CoV-2 and studies published after 1. December 2019.

((((Coronavirus[mh] OR "Coronavirus Infections"[mh] OR "corona virus"[tw] OR coronavirus*[tw] OR coronovirus*[tw]) AND (novel[tw]OR 2019[tw] OR Wuhan[tw] OR Huanan[tw])) OR "covid-19"[nm] OR "severe acute respiratory syndrome coronavirus 2"[nm] OR "COVID-19"[tw] OR COVID19[tw] OR CORVID-19[tw] OR CORVID19[tw] OR "coronavirus 2"[tw] OR "corona virus 2"[tw] OR nCoV[tw] OR 2019nCoV[tw] OR "SARS-CoV-2"[tw] OR "SARS-CoV2"[tw] OR SARSCoV19[tw] OR SARS-CoV19[tw] OR SARS-CoV-19[tw] OR HCoV-19[tw] OR WN-CoV[tw]) AND ("Equipment Contamination"[mh] OR vehicle*[tw] OR contaminat*[tw] OR "direct contact"[tw] OR fomite*[tw] OR fomes[tw] OR hand[tw] OR hands[tw] OR skin[tw] OR surface*[tw]) AND (2019/12/01:2030/12/31[edat]))

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